N95- 24125

43461
p. 21

Digital Linear Tape (DLT) Technology and Product Family Overview

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Introduction

The demand that began a couple of years ago for increased data storage capacity continues [1]. Peripheral Strategies (a Santa Barbara, California, Storage Market Research Firm) projects the amount of data stored on the average enterprise network will grow by 50 percent to 100 percent per year. Furthermore, Peripheral Strategies says that a typical mid-range workstation system containing 30GB to 50GB of storage today will grow at the rate of 50% per year. Dan Friedlander, a Boulder, Colorado-based consultant specializing in PC-LAN backup, says "The average NetWare LAN is about 8GB, but there are many that have 30GB to 300GB....."

The substantial growth of storage requirements has created various tape technologies that seek to satisfy the needs of today's and, especially, the next generation's systems and applications. There are five leading tape technologies in the market today: QIC (Quarter Inch Cartridge), IBM 3480/90, 8mm, DAT (Digital Audio Tape) and DLT (Digital Linear Tape). Product performance specifications and user needs have combined to classify these technologies into low-end, mid-range, and high-end systems applications. Although the manufacturers may try to position their products differently, product specifications and market requirements have determined that QIC and DAT are primarily low-end systems products while 8mm and DLT are competing for mid-range systems applications and the high-end systems space, where IBM compatibility is not required. The 3480/90 products seem to be used primarily in the IBM market, for interchangeability purposes.

There are advantages and disadvantages for each of the tape technologies in the market today. We believe that DLT technology offers a significant number of very important features and specifications that make it extremely attractive for most current as well as emerging new applications, such as Hierarchical Storage Management (HSM). This paper will demonstrate why we think that the DLT technology and family of DLT products will become the technology of choice for most new applications in the mid-range and high-end (non-IBM) markets.

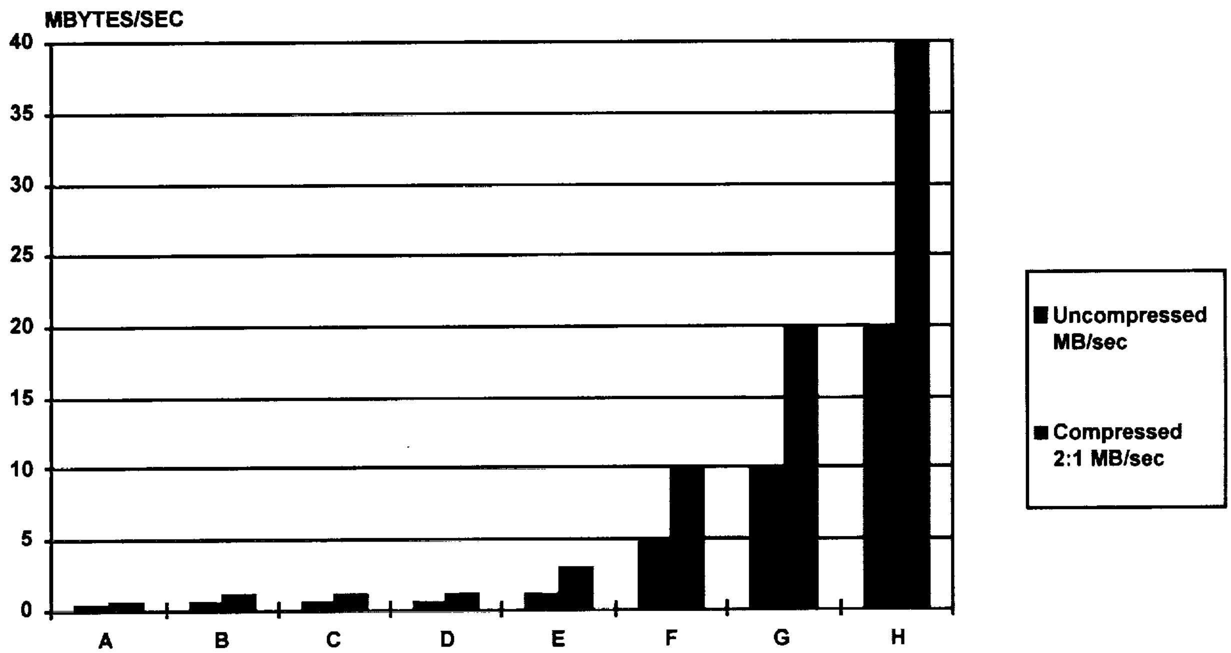
DLT Technology — Media, Mechanics, and Electronics for Performance and Reliability

The choice of using Digital Linear Technology (versus analog and/or helical scan) to develop our tape storage products was made after an in-depth analysis of the tape media and head technologies available in the late 80's. We decided on metal particle (MP) media and a tape cartridge that permits the creation of several generations of DLT products [2].

The DLT engineering development team recognized the potential of MP media early on. Products using MP technology were already using MP tape when the first DLT product was introduced into the OEM market in December, 1991, but the origin of 8mm technology was actually a consumer product that was already designed to use a consumer grade version of 8mm tape. We chose MP after an exhaustive set of tests with all of the then-available types of media, including SVHS, Barium Ferrite, Chromium Dioxide, and MP, because our testing proved to us that MP was to become technology's media of choice.

Initial reaction from a number of industry experts was that we had made the wrong decision. The pending announcement of IBM's NTP (New Tape Product) and the recent announcement of STK's REDWOOD product (both designed for high capacity and performance) are solid proof that our choice of MP media for our DLT products was correct. In addition, both the 8mm and DAT media products already depend on MP media for their newest and future generation products.

We chose linear recording technology (vs. helical scan), because, with the help of Digital Equipment Corporation system architects, we were able to foresee that transfer rate, which was not important until the early 1992 time frame, was going to be increasingly important in the future. We began with a 2-channel head design (using ferrite head technology) for the first four DLT family members. It has been established that linear recording technology allows for the increase of read/write channels with their corresponding increase in the transfer rates. Figure 1 illustrates the transfer rate potentials for the leading 4mm/8mm technologies versus linear recording technologies such as QIC and DLT. The graph illustrates ability of DLT technology to continue increasing the transfer rate of subsequent generation products by adding more parallel channels (4 channels, 8 channels, etc.).



A = 4mm, standard speed
B = 4mm, high speed
C = 8mm, 1 channel
D = 8mm, 2 channel
E = 2 channel DLT
F = 4 channel DLT
G = 8 channel DLT
H = 18 channel DLT

Figure 1: Data Transfer Rates of Competing Tape Technologies
(Based on First Generation MP Media Products)

We chose a 4" x 4" x 1" single-reel cartridge that could handle as much media as possible in a tape drive that could fit in the 5.25 inch form-factor envelope. We have already demonstrated on an earlier generation DLT product (the TZ30), that even a half-height, 5.25 inch form-factor product is possible using the DLT cartridge. The cartridge size and the half inch tape (versus quarter inch or other sizes) ensures that whatever capacities other technologies accomplish with new media (MP1, MP2, BaFe, ME etc.) the DLT products can surpass from 8 to 16 times, because of the amount of physical media area available inside the cartridge.

Figure 2 illustrates the capacity potential of various technologies. The bars indicate the physical area that the media from each of the cartridge technologies would occupy, if it was just laid out on a flat surface.

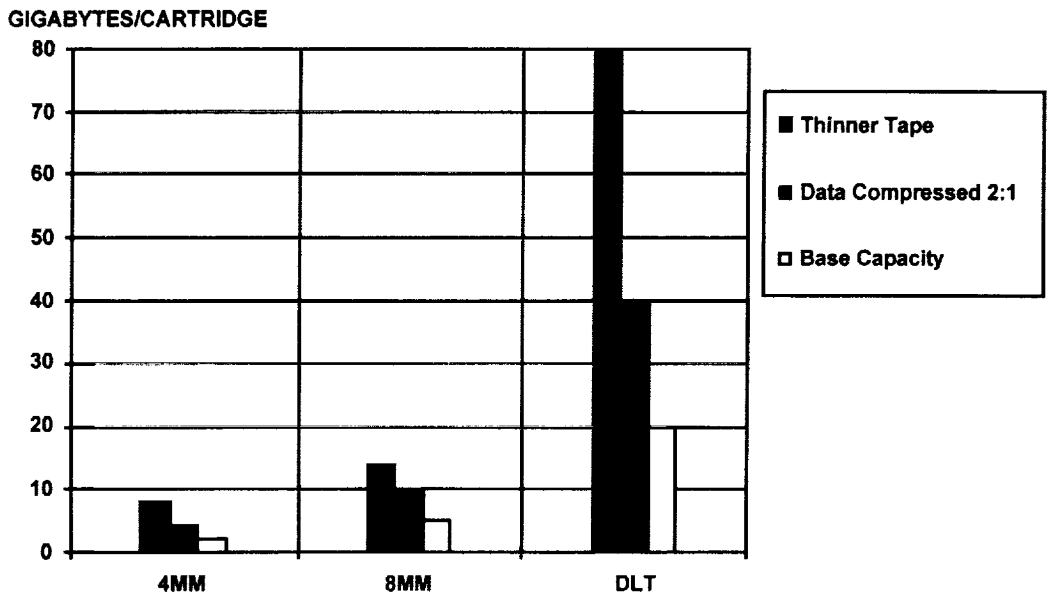


Figure 2: Capacity Potential of Various Technologies

The combination of capacity per cartridge and transfer rate, coupled with industryleading reliability and data integrity make DLT a technology ideally suited for meeting the rising demands for data storage and the clear choice of products for the balance of this decade and, possibly, well into the next.

The DLT's design features illustrate its robust nature. Mechanics, electronics, and interface have been developed to provide a platform for performance and growth.

The heart of the DLT mechanical design is the Head-Guide Assembly (HGA). The HGA is basically the tape path, with the head mounted on a head bracket in an integrated sub-assembly. The tape path is comprised of six rollers, three on each side of the head. The head bracket sits on a stepper motor lead screw that positions the head in a horizontal/vertical motion only, allowing for random access operation. The DLT uses 128 tracks, addressed in pairs by the 2-channel ferrite head in the DLT2000 product.

The primary strategy for the DLT mechanical design was to create a platform capable of multi-generation products. The original HGA design resulted in a number of patents for the basic mechanism. To achieve the tracking margin requirements [3], the off-track error budget elements are monitored and controlled continuously throughout the manufacturing process and via strict parts specifications. Furthermore, a stringent off-track test is performed on every DLT drive, prior to the"Confidence" and "Data Interchange" testing performed in manufacturing prior to shipping the product.

Because of the superior tape tracking and positioning accuracy of the HGA (Figure 3), so far there has been no need to introduce a closed loop servo control on any DLT product. Instead, the positioning accuracy throughout the entire length of tape is achieved by a combination of a pair of calibration tracks located ahead of the BOT coupled with an extensive adaptive calibration process and a series of adaptive positioning algorithms [4]. These calibration tracks, which also serve to detect the recording density of the drive, and, therefore, the specific DLT family member, are not pre-recorded. When a drive sees a blank tape cartridge, it automatically lays down the calibration tracks before any other operation takes place. From this point on, the cartridge will always indicate its recording density, thereby identifying how it should be read or written by any other DLT family member into which it is loaded. It is not possible to record multiple densities on the same cartridge.

The "buckling" mechanism is a self-threading mechanism whose reliability has been demonstrated in the over 600,000 DLT products that have shipped since 1985, spanning two generations of DLT drives (seven DLT family members). Each generation benefits from the experience of the previous generation, leading to perfection in this very critical part of the design. The need for robustness in the Load/Unload Mechanism is essential to withstand continuing punishment of the hardware in tape library environments. The DLT Load/Unload operation is heavily assisted by a number of firmware algorithms that guarantee the reliability of the DLT's mechanical operations.

There are no capstans involved in the design. The tape moves in and out of the cartridge via a precise servo control of the two reel motors. The servo control is designed to guarantee a constant 4.5 oz. tension in front of the head. The adaptive techniques mentioned earlier, however, can introduce automatic tension adjustments if the drive detects a soft area on the media or other reasons that may weaken the signal amplitude and/or resolution.

The DLT family's electronics support the design's requirement for performance and expansion. The read/write channel for most recent DLT family members (DLT2000 and DLT4000) is designed using RLL (2, 7) recording technique. The bit density of the DLT4000 is 82,500 bits per inch (bpi). The tape speed is constant at 110 Inches Per Second (IPS) during read and write operations. The best way to describe the sophistication of the electronics, is to discuss some of the areas of adaptive techniques in the design: servo and tape thickness adaptation, track positioning, head media mechanics and electronics, and data position "learning".

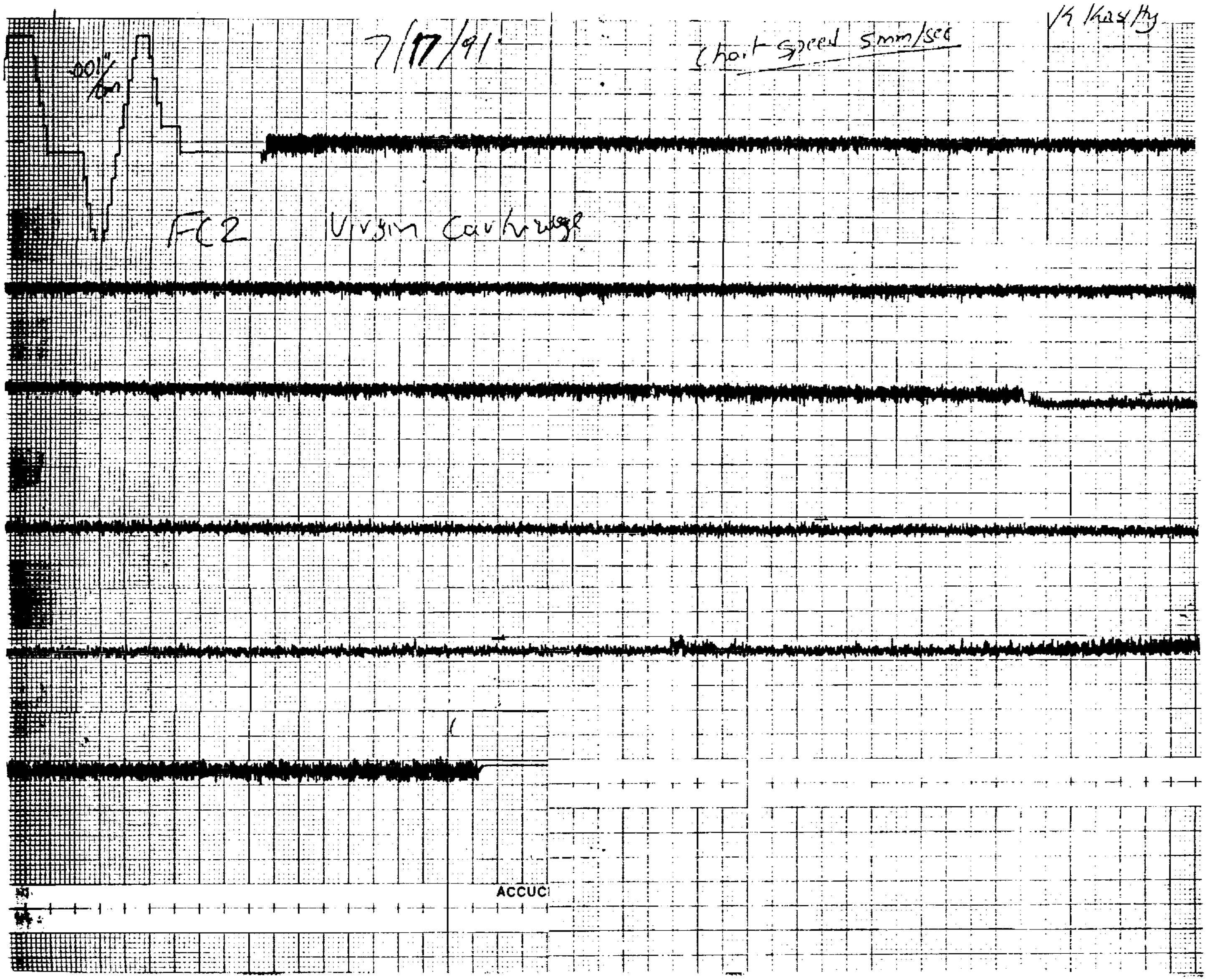


Figure 3. Signal Trace Showing Lateral Motion of Tape (HGA Tracking)

Mechanical variation of the media (which may result from manufacturing process tolerances, for example), if not properly compensated for, can result in operation failures or a control system that runs at a sub-optimal performance level. If this occurs, the tape thickness and other dimensions are actually measured by the drive. The results of these measurements are used for the various servo optimizations.

As indicated earlier, newly-purchased tapes are completely empty of data. The drive will detect a blank tape and write on it a pair of calibration tracks. These calibration tracks are written only once. The drive uses these tracks (located ahead of the BOT physical hole), much the same way as a disk drive uses its servo tracks (a detailed description of the calibration tracks' location and handling is provided in the DLT ANSI and ECMA standards.) Accuracy in tape path design and manufacturing assembly is essential to guarantee interchangeability without the need for additional servo information recorded anywhere on the 1,100+ feet (DLT2000 cartridge) or 1,700 feet (DLT4000 cartridge) of tape.

The DLT position algorithms are extremely accurate. They are able to determine the track centerline to within 100 micro inches accuracy using extensive filtering and various interpolation techniques.

At current DLT product densities (82.5 KBPI), any manufacturing process variation can result in loss of signal. To minimize tolerance sensitivities and improve manufacturing yields, our DLT design utilizes a completely adaptive channel. Every time a previously written cartridge is loaded, the drive adjusts its read/write electronics to ensure optimum operation. These adjustments are not a simple correction but a very complex estimation theory based on past experience with adaptive techniques.

The following parameters are automatically adjusted: write current, operating controls (tension, position, etc.), mechanical offsets (head adjustments, etc.), and automatic gain controls/channel control/various responses, etc.

The DLT drive's intelligence actually extends into "learning" the data on the tape. Information such as "end of data" (EOD) location and Tape Mark (TM) counts allow the DLT to find data boundaries at very fast access times by using diagonal searches. The DLT2000 and DLT4000 drives can search for Tape Marks at 150 IPS (a 300+ Mbyte/sec. equivalent search speed.) The Tape Mark directory is totally transparent to the user and is maintained and updated automatically following the completion of a write operation.

The DLT calibration process completely replaces the familiar electrical and mechanical factory adjustment that most of today's tape drives require: There are no pots, capacitors, head adjustments or any other fine tuning. All adjustments are done by the two on-board microprocessors during the calibration stages.

One of the unique (and well patented) features of the DLT design is its superior head and media interface implementation. The DLT's unique head design alone deserves a separate paper. The head is ferrite with MIG. It has six elements (2 x W-R-W channels operating simultaneously). Figure 4 shows the head geometry configuration.

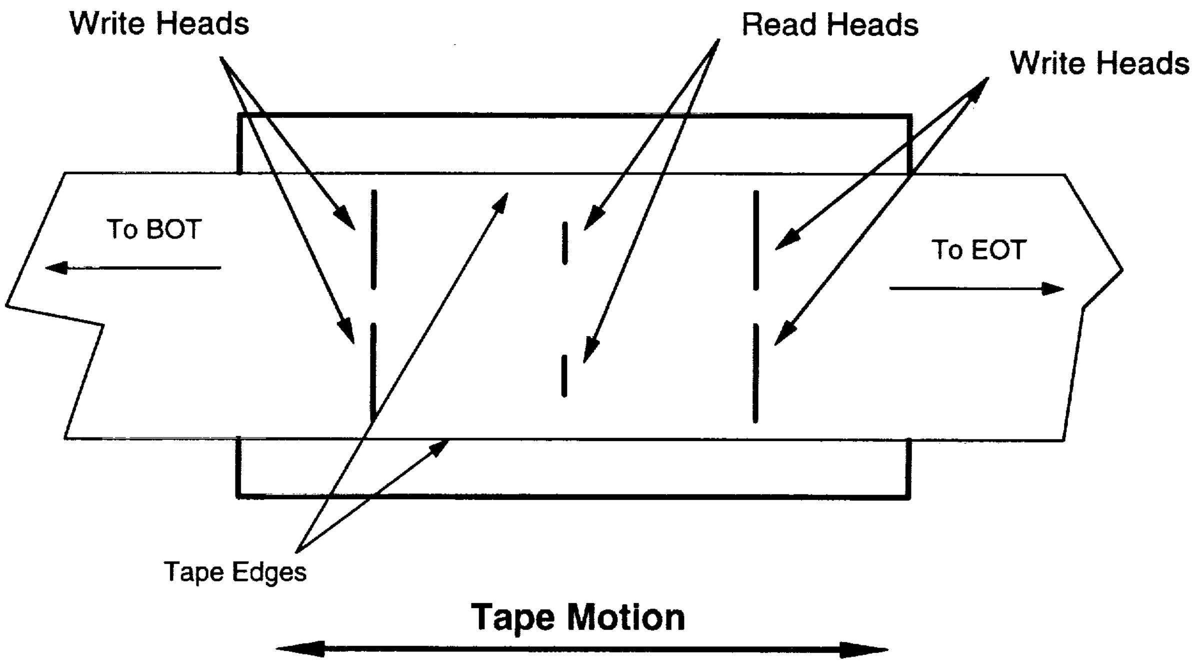


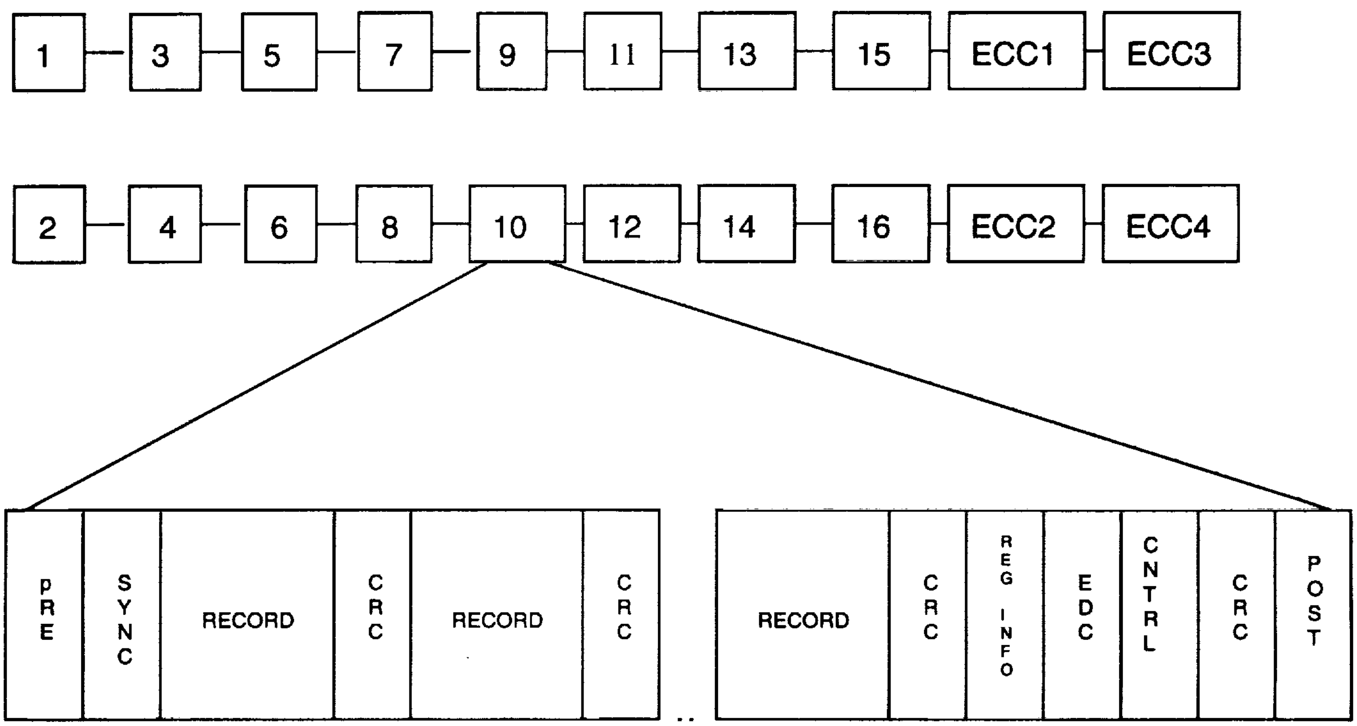
Figure 4: DLT Head Geometry Configuration

The write-read-write placement of the gaps allows for "read while write" operation in both directions. This unique design of head elements and contour combine to give the DLT products great areal density capability as well as self-cleaning behavior. The unique contour design virtually eliminates any separate head cleaning operation. A cleaning cartridge is available, but only to be used when the drive illuminates the cleaning indicator on its front panel.

The combination of the head contour design and low tape tension results in a head life that exceeds 10,000 hours (at 100% duty cycle). The length of DLT head life is a significant advantage over other technologies when robustness is necessary for high duty applications. The gentleness and accuracy of the tape path design, coupled with the head contour design, low tension and the quality of the MP media itself contribute to a tape durability that exceeds 500,000 passes (a "pass" is defined the movement of a single segment of tape under the head). Assuming a worst case scenario, one cartridge can be used 10,000 times to completely write or read all 128 tracks (64 pairs) in the serpentine mode.

Our data on life and durability of the DLT tape shows that to date we have been unable to find a measurable end of life for the tape. Our tests in environmental chambers have been designed to simulate 10 years of actual, continuous drive operation, and the tests are still running. The number of passes the still-readable tape has made over the head is now approaching 1,000,000. One of the original requirements for the DLT product family, was to implement an "Industrial Strength" class of data integrity and reliability algorithms. The results of our design approach are an unsurpassed combination of data detection and correction algorithms that produce a "Hard Error Rate" of 1×10^{-17} bits read and a combined theoretical overall undetected error rate of 1×10^{-30} bits read.

Figure 5 shows the data format for the DLT2000 and DLT4000 products. The format consists of multiple "entities." An entity is comprised of 16 x 4K data blocks and 4 x 4K ECC blocks. Within the entity, the format supports record sizes varying from 1 byte to 16 Kbytes, as Figure 5 indicates. At the end of each record (regardless of size), the drive records a 16-bit cyclic redundancy check (CRC). At the end of each physical 4K block, the drive records a 64-bit CRC that checks the entire 4K block with as many records as it contains. The entity is protected by a "Block-Level Interleaved Reed-Solomon ECC" code, that occupies the last four 4K-blocks of the entity. The ECC algorithm is capable of correcting any four 4K-blocks at any place within the 20 block entity (including the ECC field itself). In terms of physical tape space, it is possible to remove a half-inch section of the tape and the drive will be able to accurately reconstruct the missing information. There is a detailed description of the DLT format and ECC/CRC algorithms in the applicable ANSI and ECMA Standards documents.



20 Block Entity: 16 Data and 4 ECC

Figure 5: DLT2000/DLT4000 Media Format

In addition to the ECC and CRC error detection and correction features, the DLT drives are capable of using "track centerline offsets" (like disk drives) to attempt to recover the data as part of the automatic hard error recovery procedure. No software intervention is needed for the hard error recovery process to be invoked.

The Data Compression Algorithm chosen for the DLT2000 and succeeding products, is a variant of Lempel-Ziv (LZ1). The DLT Engineering Development Group chose LZ1 (versus IBM's IDRC), after prototyping both algorithms with identical DLT Tape Drives in the Engineering Labs [5]. It was expected that the IDRC prototype would out-perform the LZ1 prototype because it had, potentially, almost twice the data throughput. It was also expected that the two competing algorithms would have roughly the same compression ratios, with the LZ1 ratio being only slightly higher. Test results showed, however, that in the DLT environments the LZ1 consistently exceeded the IDRC performance in both metrics. The IDRC compression efficiency results were also confirmed by benchmarking against other tape products that use the IDRC algorithm.

Figure 6 shows the measurements of compression ratio on VMS and UN*X systems. The difference in compression ratio between the LZ1 and IDRC prototypes show that the LZ1 prototype had significantly higher compression ratios for all the data types that were tested.

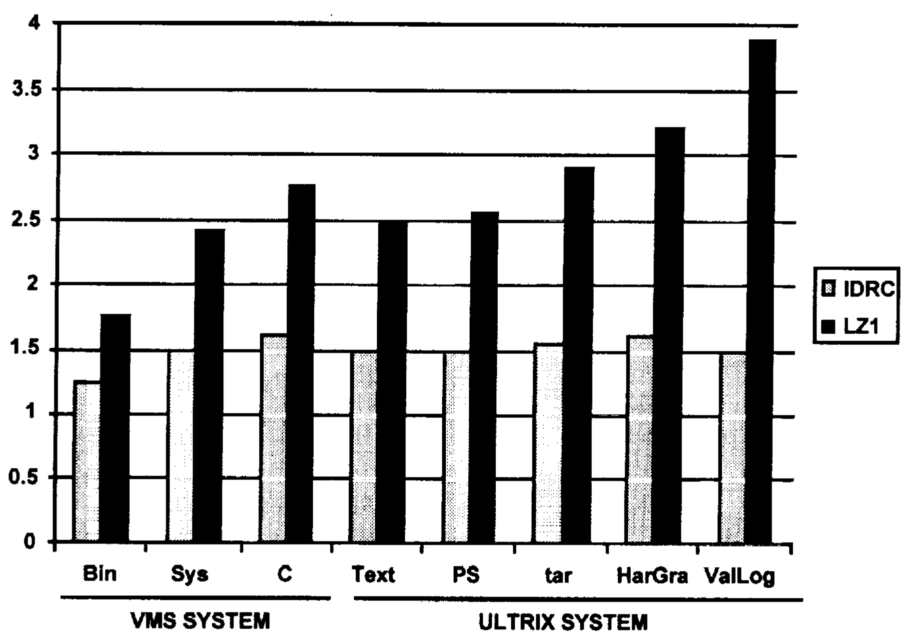


Figure 6: Operating System Compression Results

Figure 7 shows the SDS-3 based compression test results. The first four data types show the LZ1 prototype averaging around 2.4:1 and the IDRC prototype around 1.5:1. For the paintbrush bitmap file, both versions compressed at about the same efficiency.

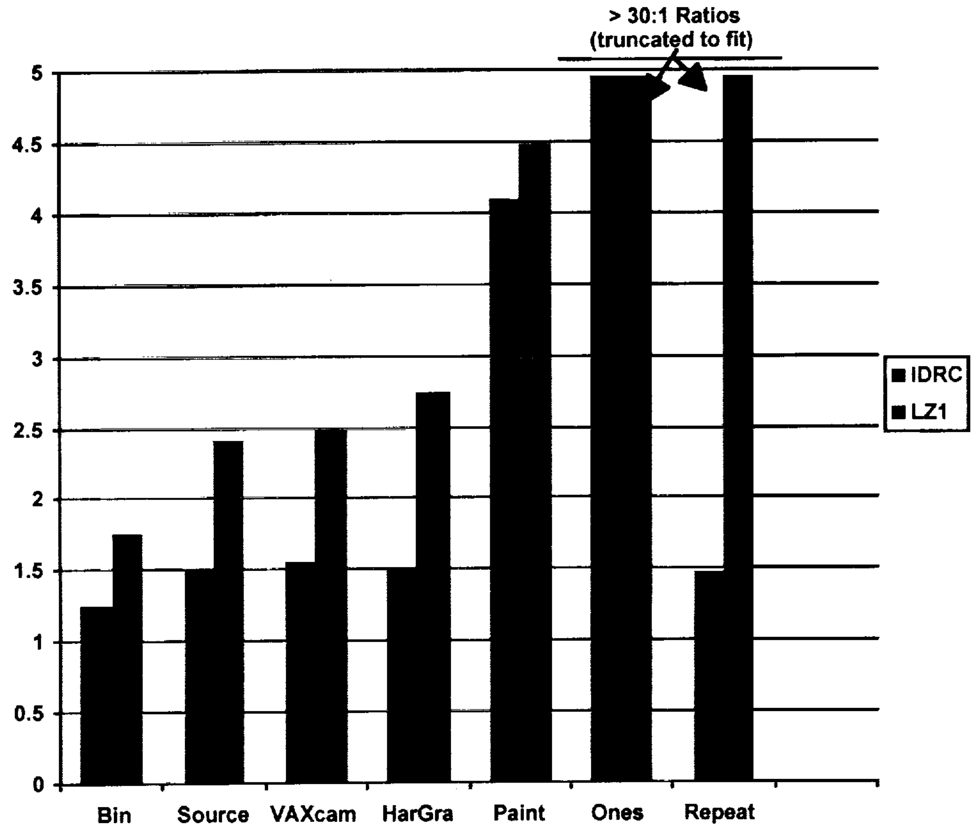


Figure 7: SDS-3 Data Compression Results

The lab test results showed that, on average, the LZ1 efficiency was at a 2.5:1 ratio vs. the IDRC's 1.5:1 ratio. Quantum Corp. has a white paper available that provides the details of these tests.

The DLT design supports both data compression and compaction. The advantage of the compaction algorithm is that there is no loss of recording space on the tape. Even if the file ends anywhere within a given entity (see Figure 5), the first record of a new file will begin immediately after the end of the previous file without any loss of media space. The drive automatically regenerates the ECC algorithm to cover the new information within the entity.

To summarize, the description of the major design areas of the DLT given above, although brief, exemplify a product designed for maximum reliability. The very gentle head-to-media interface (HGA design), the self-cleaning properties of the head, the extensive use of adaptive techniques, and the very long media and head life tests under extreme environmental conditions, all contribute to the reliability and robustness of the DLT products. Using the "HP Method" of recording failures in the field (i.e., all types of failures are taken into account during a power on period of 24 hours a day, seven days a week), the DLT products are exceeding their specified mean time between failure (MTBF) rate of 80,000 hours by 25%, independent of duty cycle. Two of the major contributors to this field MTBF performance are the 10,000 hour head life and media durability.

THE DLT PRODUCT FAMILY AND APPLICATIONS

Until the last couple of years, the primary function of the tape drive has been to backup and archive data. As data storage requirements have been increasing at an almost exponential rate, the need for a balance of capacity and performance has become much more critical. With 20GB of native data recorded on a single DLT4000 cartridge, the user needs to transfer the data in the shortest time possible. That is the reason the DLT product family emphasizes overall performance as much as capacity per cartridge. Figure 8 shows the DLT Product Family (second generation), beginning with the DLT260, which was first introduced in November, 1991, as a product aimed at the OEM market. The DLT260 was followed by the DLT600 in mid-1992, and the DLT2000 (our current high volume product), introduced in the third quarter of 1993. The DLT2000, with a capacity of 10GB per cartridge (native) and 1.25MB/sec. (native), is today's industry leader for this class of products. The new DLT4000, with volume production starting early in calendar 1994, stretches the DLT technology leadership that much further (note especially the considerable improvements in load times)..

	DLT260	**DLT600**	**DLT2000**	**DLT4000**
Data Rate (MB/s, Native)	.800	.800	1.25	1.5
Capacity (GB, Native)	2.6	6	10	20
Bit Density (bpi)	42,500	42,500	62,500	82,500
Track Density (tpi)	96	224	256	256
Media Type	MP-1	MP-1	MP-1	MP-2
Media Length (in feet)	1100	1100	1100	1700
Recording Channels	2	2	2	2
Data Compression	No	No	Yes	Yes
Load Time (in seconds)	60	60	45	33

Figure 8: Quantum DLT Drive Product Family

By intent, the transition from the DLT2000 to the DLT4000 product was an evolutionary development effort. As Figure 8 shows, the primary changes were the combination of the thinner MP media (MP2) and a higher bit density (82.5 KBPI). Minor modifications to the head were necessary, as well as the incorporation of a flex circuit containing the read pre-amp in much closer proximity to the head. Specifically, the head core geometry was slightly changed, but the contour and all other electrical and mechanical parameters remained fairly close to the DLT2000 configurations.

Quantum offers not only the drive itself: The DLT product family includes a 7-cartridge loader (half-rack form-factor, for rackmount applications) and a compact 5-cartridge loader designed for table-top applications. The design concept for the two loaders has been to enable the replacement of the drive only (inside the loaders) in the field by a skilled technician.

In addition to loaders, a number of third-party robotics companies have announced and are shipping both large and small library configurations. Figure 9 shows the vendors that offer libraries for the DLT family of products. It has become clear in the marketplace that the primary growth in the tape industry is in these library configurations. A number of tape manufacturers of various technology products (DAT, 8mm, 3480/90, etc.) today offer an assortment of library products extending from 28 cartridges to 900 cartridge robots. The library vendor differentiation is in terms of the number of cartridges in the library and the ratio of cartridges to drives that the robot can handle. A number of additional library vendors are developing DLT-based products, anticipating even more capacity and higher performance DLT products.

COMPANY	LIBRARY	DLT PRODUCT	DESCRIPTION	CAPACITY*
Quantum	DLT2500 DLT2700 DLT4500 DLT4700	DLT2000 DLT2000 DLT4000 DLT4000	5 Cart.Loader, 1 drive 7 Cart.Loader, 1 drive 5 Cart.Loader, 1 drive 7 Cart.Loader, 1 drive	50 GB 70 GB 100 GB 140 GB
ATL/Odetics	ACL2640	DLT2000	264 Cartridge Library, 3 drives	2.64 TB
Breece Hill Technology	Q7 Q47	DLT2000 DLT2000	28 Cartridge Library, 3 drives 60 Cartridge Library, 2 - 4 drives	280 GB 600 GB
Digital Equipment Corporation	StorageWorks TL820	DLT2000	264 Cartridge Library, 3 drives	2.6 TB
Overland Data	DLT Multilibrary DLT TA200 Tape Array Subsystem	DLT2000 DLT2000	24 - 120 Cartridge Library, 1 - 8 drives	240 GB - 1.2 TB 100 GB
Metrum	D900 D360 D480 D28 D60	DLT2000 DLT2000 DLT2000 DLT2000 DLT2000	900 Cartridge Library, 20 drives 360 Cartridge Library, 8 drives 480 Cartridges (add on to D360) 28 Cartridge Library, 4 drives 60 Cartridge Library, 2 - 4 drives	9 TB 3.6 TB 280 GB 600 GB

* All capacities are native.

Figure 9: Quantum DLT Drive-Based Tape Libraries

COMPANY	LIBRARY	DLT PRODUCT	DESCRIPTION	CAPACITY*
ADL - Media Logic	SLA-Dbase	DLT2000/4000	1 - 2 drives, 7 or 14 cartridges	70 GB - 280 GB
	SLA-Dplus	DLT2000/4000	2 - 4 drives, 7/14/26 cartridges	70 GB - 520 GB
	SLA-Dmax	DLT2000/4000	2 - 7 drives, 7/14/26/50 cartridges	70 GB - 1.0 TB
ADIC (Applied Digital Inter. Corp)	N/A	DLT2000	1 - 8 drives, 24 - 120 cartridges (12 cartridges per magazine)	240 GB - 1.2 TB
APP/Grau	ABBA/2	DLT2000	Up to 100,000 cartridges (mixed media environment)	
	ABBA/E	DLT2000	Up to 12,000 cartridges (mixed media environment)	

* All capacities are native.

Figure 9: Quantum DLT Drive-Based Tape Libraries (Continued)

The increasing popularity of the DLT has led an impressive list of third-party software vendors to support the DLT family of products and options. Figure 10 shows a partial list of software companies that support DLT options under all the major operating systems platforms. There is a considerable list of additional software companies who are currently developing support for the DLT drives and options (in both Loader and Library configurations).

Operating System	Application Software
Netware	Avail 2.0 Cheyenne Arcserve NLM 4.02 & 5.01E Systems Enhancement V 1.95 Novastor Novanet Arcada HSM, Backup Exec Palindrome Backup 3.1, Network 3.1, HSM 3.1
Windows 3.1	Cheyenne ARCsolo for Windows Novastor Backup for Windows
Windows NT	Arcada Backup Exec for NT Microsoft Backup (NT 3.5)
DOS	Cheyenne ARCsolo for DOS Novastor Backup for DOS Palindrome Director for DOS 3.1 Palindrome Backup Network Archivist for DOS 3.1
OS/2	Novastor Backup for OS/2 Legato (SUNOS 4.1, Solaris 2.3, RS6000 AIX) Novastor SGI/IRIS>5.X, RS6000 AIX, ATT/GIS System 5 Novastor (Sun Solaris 2.3, HP9000/400/700, SunOS 4.1, .2, .3 Cheyenne ARCserve/open 2.0 (Solaris 2.3, RS6000 AIX)
HP-UX, AIX	Workstation Solutions/Quick Restore
SCO UNIX	SCO STP Driver
Apple System 7	Dantz (Retrospect 2.1A/Retrospect DLT Driver) Novastor NovaMac

Figure 10: DLT Software Connectivity Matrix (Partial List, Valid as of 11/30/94)

For those proprietary platforms into which DLT products have not yet been integrated by the systems manufacturer, a number of Value Added Resellers (VARs) and Systems Integrators have developed and offer emulations that enable the DLT products to be attached to these proprietary busses as well.

Considering that the popularity of Hierarchical Storage Management (HSM) is increasing (based on the premise that the data storage requirements at the system level are increasing dramatically every year), it is probably worth discussing the DLT's potential for making HSM work most efficiently and economically [6].

In a recent article on HSM in the "Client/Server Today" magazine (December, 1994), David Simpson states that "HSM has the potential to dramatically reduce storage costs and management hassles by migrating infrequently accessed or inactive files from expensive disk drives to less expensive storage devices." The value of HSM is that this migration happens automatically and is transparent to the user. To differentiate between the various HSM packages available in the market today, Peripheral Strategies developed a set of definitions for the five levels of HSM software. Depending on the application, a user can select the particular HSM level that incorporates the various storage devices and/or technologies most suited for use with the range of data.

DLT products are ideally suited to become the products of choice for HSM applications. They offer the highest capacity and performance combination in industry today for their class of products. In addition, a number of software companies offer HSM software support for the DLT products. In December, 1994, Cheyenne Software, a leading supplier of software products for all major systems platforms, announced support for the DLT2000 drives within its new HSM program in addition to on all its other software platforms via the company's ArcServe and ArcSolo software packages. Avail Systems, Arcada Software Inc., Axent Technologies, Epoch Systems, Legato System Inc., Novastor Corp. and Systems Enhancements Inc. have also announced DLT support on their HSM solutions as well as on their other software platforms.

The next step in the DLT family development is another 5.25 inch form-factor product with higher native capacity per cartridge and substantially higher native performance. This new product will use the DLT4000 cartridge and will, of course, be read/write compatible with the previous members of the DLT Family. This new product will be announced in the second half of 1995.

For future family members, the DLT Development Group is planning to take advantage of all head and media technologies that other tape manufacturers who are using smaller form-factor cartridges are bringing to market to keep up with the constantly increasing demand for much higher capacities and increased performance. Because of the physical dimenstions of its cartridge and the cartridge's designed-in ability to incorporate more tape, the DLT engineering team can continue to offer industry-leadership storage capacity and products, always able to embrace the advances other manufacturers make in tape media and head technologies.

Our DLT development team plans to take advantage of thin-film-head technology for its multi-channel head requirements. Metal Evaporated (ME) tape and/or Barium Ferrite (BaFe) tape technologies, which are now being developed for the QIC and 8mm applications, also show some potential for use in DLT technology. Our product map calls for products to be developed with 100GB of native capacity per cartridge with 10-15 MB/sec. native transfer rates by the end of this decade. At this point, we intend to continue to maintain, at a minimum, read compatibility with all prior generation DLT products.

Summary

DLT is a mature and robust technology that has finally been "discovered" by the computer market because it offers the capacities, performance, and reliability that today's systems applications require. There is no other technology or product set available today that offers so balanced a combination of capacity and performance with leadership in data integrity and overall product reliability. With those strengths and their cost of ownership, these products are the best tape storage solution in the industry.

Advancements in DLT technology guarantee that new family members will continue to be developed for the balance of this decade and well into the next. Unless a new technology emerges to obsolete tape media products, DLT will continue to be the tape industry leader for this class of products.

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